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EFFECT OF NANO UREA AND NANO DAP ON GROWTH AND YIELD OF POTATO (*Solanum tuberosum* L.)

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ABSTRACT

The present investigation entitled, "Effect of nano urea and nano DAP on growth and yield of potato (*Solanum tuberosum* L.)" was carried out at Experimental Farm, Department of Agriculture, Mata Gujri College, Fatehgarh Sahib, Punjab during *rabi* season of 2023-2024. The experiment was laid out in randomized block design with nine treatments *viz.*,T_1: control, T_2: 100% RDF, T_3: 75% RDF, T_4:75% RDF + foliar application of nano urea at 30 DAS, T_5: 75% RDF + foliar application of nano DAP at 30 DAS, T_6: 75% RDF + foliar application of nano urea and nano DAP at 30 DAS, T_7: 50% RDF + foliar application of nano urea at 30, 45 DAS, T_8: 50% RDF + foliar application of nano DAP at 30, 45 DAS, T_9: 50% RDF + foliar application of nano urea and nano DAP at 30, 45 DAS. The doses of nano fertilizers were sprayed @ 4 ml l^{-1} of water. The results revealed that the different treatments had significant effect on growth and yield parameters at harvest stage. The further significantly maximum plant height (65.07 cm), dry matter accumulation (24.33 g), leaf area index (4.83), number of tubers plant^{-1} (15.10), weight of tubers plant^{-1} (750.33 g), tuber yield plot^{-1} (28.15 kg), total yield of tuber (335.08 q ha^{-1}), unmarketable yield (2.20 q ha^{-1}), marketable yield (332.88 q ha^{-1}), biological yield (416.74 q ha^{-1}) and harvest index (80.56 %) was recorded with the application of 75% RDF + foliar application of nano urea and nano DAP at 30 DAS which was at par with 50% RDF + foliar application of nano urea and nano DAP at 30,45 DAS and 50% RDF + foliar application of nano DAP at 30,45 DAS. These treatments were significantly superior over rest of treatments and control.

(Key words: Foliar application, nano DAP, nano urea, growth and yield parameters)

INTRODUCTION

Potato (*Solanum tuberosum* L.) belongs to the family Solanaceae, is a wonder food crop referred as a "King of vegetable". The probable centre of origin of potato is South America in the Central Andean region. Evidences indicate that potatoes were cultivated for centuries by South American Indians and the tubers were used as a common article of food. The Spanish people brought potato from Peru to Spain in 1565 (Singh *et al*., 2010). Potato occupies prime position among the cash crops in India.

The potato is a starchy, tuberous crop from the perennial nightshade. The word "potato" may refer either to the plant itself or to the edible tuber. Potatoes have high nutritional value. It is rich source of vitamin C, B_1 and minerals or starch. It contains 20.6% carbohydrate, 2.1% protein, 0.3% fat, 1.1% crude fibre (Singh *et al*., 2008).

The application of inorganic fertilizers have been found to have lower fertilizer use efficiency in potato crop which ranges from 20 to 50 % nitrogen, 10 to 25 % for phosphorus and 70 to 80 % for potassium owing to leaching, volatilization and denitrification losses which contribute to greenhouse gases emission (Chinnamuthu and Boopathi, 2009).In this situation, the nano fertilizer is good option to overcome these drawbacks, nanotechnology holds promise and nano-fertilizers provide a way in ensuring sustainable soil health and higher crop production (Lal, 2008). Nano fertilizers have unique properties that make them potentially useful for improving plant growth and reducing environmental pollution. Nano sized particles will tolerate the plasma membrane in plants and animals, water solubility, nanotechnology use this method to deliver at the cellular level which is simpler than the traditional methodology, high surface energy (Jadav *et al*., 2023). It can reduce runoff and nutrient leaching into the environment, improving environmental sustainability. They can also improve fertilizer use efficiency, leading to higher crop yields and reducing the overall cost of fertilizer application. Nano urea increases its availability to crop by more than 80% resulting in higher nutrient use efficiency (Yadav *et al*., 2023). Nano-fertilizers provide nutrients in a slow and study way to the crop as per the requirement in order to increased crop yield, improve quality and to improve the overall sustainability of

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agriculture system (Tarafdar *et al*., 2014). Nano fertilizers also play an important role in soil health by building up soil organic carbon, improving soil aggregation and water holding capacity as well as regulate the release of nutrients more efficiently than ordinary fertilizers (Liu and Lal, 2015). Nano urea contains 4.0% total nitrogen. Nano particles size varies from 20-50 nm. Nano DAP formulation contains nitrogen (8.0% N w/v) and phosphorus (16.0 % P_2O_5 w/v). Nano DAP (Liquid) has advantage in terms of surface area to volume as its particle size is less than 100 nanometer (nm). Better spread ability and assimilation of nano DAP inside the plant system leads to higher seed vigour, more chlorophyll, photosynthetic efficiency, better quality and increased in crop yields (Anonymous, 2023). Thus, nano-fertilizers have the potential to enhance crop productivity by increasing nutrient use efficiency.

MATERIALS AND METHODS

In the *rabi* season of 2023-2024, an investigation was carried out at experimental farm, Kharora, department of Agriculture, Mata Gujri College, Fatehgarh Sahib, Punjab. The experimental site is located at subtropical plains of Punjab at an elevation of 246 meters above the mean sea level. The sites represent 30Ú - 27Ú and 30Ú - 46Ú N latitude and 76Ú - 46Ú and 76Ú - 78Ú E longitude. The physical and chemical properties of soil were tested in laboratory prior to the commencement of trial. The proportions of sand, silt and clay were determined to be 40.20, 32.84 and 2.96 %, respectively; resulting in soil texture classified as sandy loam. The electrical conductivity was observed to be 0.57 dS m^{-1}, pH was found to be 7.1 and the organic carbon content of the sample was determined to be 0.69 %. The available nitrogen, phosphorus and potassium in the soil were 288.20, 18.31 and 168.5 kg ha^{-1}, respectively these were estimate as per method suggested by Jackson (1973). The maximum and minimum temperature recorded was 35.6 C and 20.1 C respectively. The mean average relative humidity was 95.14% during the crop growth. The total rainfall received during the crop growth period was 210.4 mm. Potato was planted from first week of October to third week of October during 2023 *rabi* season. The randomized block design with nine treatments were used to organize the field experiment *viz*., T_1: control, T_2: 100% RDF, T_3: 75% RDF, T_4:75% RDF + foliar application of nano urea at 30 DAS @ 4 ml l^{-1} of water, T_5: 75% RDF + foliar application of nano DAP at 30 DAS @ 4 ml l^{-1} of water, T_6: 75% RDF + foliar application of nano urea and nano DAP at 30 DAS @ 4 ml l^{-1} of water, T_7: 50% RDF + foliar application of nano urea at 30, 45 DAS @ 4 ml l^{-1} of water, T_8: 50% RDF + foliar application of nano DAP at 30, 45 DAS@ 4 ml l^{-1} of water, T_9: 50% RDF + foliar application of nano urea and nano DAP at 30, 45 DAS@ 4 ml l^{-1} of water. The row to row spacing was kept 60 cm and plant to plant spacing was kept 10 cm. The crop was sown on 11th October 2023 and harvest on 11th January 2024. All the recommended package of practices were followed to raise the crop. Regular biometric observations i.e. plant height and dry matter accumulation were recorded at periodic intervals of 30, 60 and at harvest stage from five randomly selected plants. Leaf area was recorded and their leaf area index was calculated by given formula (Watson, 1947).

$$\text{LAI} = \frac{\text{Leaf area (cm}^2\text{)}}{\text{Ground area (cm}^2\text{)}}$$

Where, LAI indicates the Leaf Area Index. The yield attributing characters like number of tubers $plant^{-1}$, weight of tubers $plant^{-1}$(g), tuber yield $plot^{-1}$ (kg), total tuber yield (q ha^{-1}), unmarketable yield (q ha^{-1}), marketable yield (q ha^{-1}) and biological yield (q ha^{-1}). were recorded at harvest stage. The data were analysed as per the standard procedure as described by Panse and Sukhatme (1978).

RESULTS AND DISCUSSION

Growth parameters

The data presented in Table 1 shows that the effect of nano urea and nano DAP on growth attributing characters like plant height and dry matter accumulation increased up to at harvest. The results revealed that plant height and dry matter accumulation of potato were significantly influenced by the foliar sprays of nano fertilizers except 30 DAS. However, the maximum plant height and dry matter accumulation at 30 DAS (27.00 cm and 6.07 g) was recorded with the application of 100% RDF (T_2) and minimum plant height and dry matter (24.73 cm and 4.83 g) was recorded in control (T_1). At 60 DAS and harvest stage, the maximum plant height and dry matter (60.33, 65.07 cm and 20.10, 24.33 g) was recorded with the application of 75% RDF + foliar application of nano urea and nano DAP at 30 DAS @ 4 ml l^{-1} of water (T_6) which was at par with 50% RDF + foliar application of nano urea and nano DAP at 30,45 DAS @ 4 ml l^{-1} of water (T_9) and 50% RDF + foliar application of nano DAP at 30 and 45 DAS @ 4 ml l^{-1} of water (T_8). These treatments were significantly superior over control and rest of treatments in a descending manner. Similarly, the application of 50% RDF + foliar application of nano urea at 30, 45 DAS @ 4 ml l^{-1} of water (T_7) also significantly superior over control and it was at par with 75% RDF + foliar application of nano DAP at 30 DAS @ 4 ml l^{-1} of water (T_5), 75% RDF + foliar application of nano urea at 30 DAS @ 4 ml l^{-1} of water (T_4), 100% RDF and 75% RDF (T_3). However, the minimum growth attributing characters were recorded in control (T_1). The maximum leaf area (2895.66 cm^2 $plant^{-1}$) was recorded in treatment 75% RDF + foliar application of nano urea and nano DAP at 30 DAS @ 4 ml l^{-1} of water (T_6) which was at par with 50% RDF + foliar application of nano urea and nano DAP at 30,45 DAS @ 4 ml l^{-1} of water (T_9), 50% RDF + foliar application of nano DAP at 30 and 45 DAS @ 4 ml l^{-1} of water (T_8) and it was significantly superior over control and rest of treatments. Minimum leaf area (1459.87 cm^2 $plant^{-1}$) was recorded in control (T_1). The further data showed that the area index at 60 DAS (4.83) was significantly influenced by the treatment 75% RDF + foliar application of nano urea and nano DAP at 30 DAS @ 4 ml l^{-1} of water (T_6) which was at par with 50% RDF + foliar application of nano Urea and nano DAP at 30,45 DAS @ 4 ml l^{-1} of water (T_9), 50% RDF + foliar application of nano DAP at 30 and 45 DAS @ 4 ml l^{-1} of water (T_8) and 50% RDF + foliar application of nano urea at 30, 45 DAS @ 4 ml l^{-1} of water (T_7) and it was significantly superior over control and rest of treatments. Minimum leaf area index (2.40) was recorded in control (T_1). The increased growth attributes might be due to use of nano urea and nano DAP, which play a major role in synthesis of protein, enzyme activating, oxidation, revival reaction and metabolism of carbohydrates. Growth as well as yield performance of potato crop increased by utilizing fertilizer containing nitrogen and phosphorus. Due to lack of nutrients, there is decline in photosynthesis rate which is resulted in poor growth characters and crop production. Enhanced chlorophyll concentration might have increased the light interception, absorption and utilization of solar radiation thus enhanced photosynthesis which was reflected in leaf area index. Neogi and Das (2022) reported that the application of 100% RDF of NPK along with foliar application of both nano nitrogen and nano-zinc was the best treatment in increasing the growth and productivity of potato. Manikanta *et al.* (2023) observed that growth, yield attributing characters and nutrient uptake were significantly influenced by different treatments. They reported that the higher growth parameters were recorded in treatment RDF (50% N, 50% Zn and 100% PK) + 1st spray of nano N at 25-30 DAP + 2nd spray of nano Zn after 10-15 days of 1st spray + 3rd spray of nano Cu after 10-15 days of 2nd spray.

Yield parameters

The data presented in Table 2 shows significant effect of nano urea and nano DAP on yield and yield parameters. The results showed that the number of tubers plot^{-1}, and tuber yield plot^{-1}(kg) were influenced significantly due to application of different treatments. The maximum number of tubers plot^{-1}, weight of tuber plant^{-1} (g) and tuber yield plot^{-1} (kg) (15.10 and 28.15 kg) were recorded with the application of 75% RDF + foliar application of nano urea and nano DAP at 30 DAS @ 4 ml l^{-1} of water (T_6) which was at par with 50% RDF + foliar application of nano urea and nano DAP at 30,45 DAS @ 4 ml l^{-1} of water (T_9) and 50% RDF + foliar application of nano DAP at 30 and 45 DAS @ 4 ml l^{-1} of water (T_8) and it was significantly superior over control and rest of treatments. Further data showed that the application of 50% RDF + foliar application of nano urea at 30, 45 DAS @ 4 ml l^{-1} of water (T_7) recorded significantly higher number of tubers plant^{-1} and tuber yield plot^{-1} (kg) and it was at par with 75% RDF + foliar application of nano DAP at 30 DAS @ 4 ml l^{-1} of water (T_5), 75% RDF + foliar application of nano urea at 30 DAS @ 4 ml l^{-1} of water (T_4), 100% RDF (T_2) and 75% RDF (T_3). The maximum weight of tuber plant^{-1} (750.33 g) was recorded with the application of 75% RDF + foliar application of nano urea and nano DAP at 30 DAS @ 4 ml l^{-1} of water (T_6) which was at par with 50% RDF + foliar application of nano Urea and nano DAP at 30,45 DAS @ 4 ml l^{-1} of water (T_9) and 50% RDF + foliar application of nano DAP at 30 and 45 DAS @ 4 ml l^{-1} of water (T_8) and it was significantly superior over control and rest of treatments. The application of 50% RDF + foliar application of nano urea at 30, 45 DAS @ 4 ml l^{-1} of water (T_7) recorded significantly higher weight of tubers plant^{-1} and it was at par with 75% RDF + foliar application of nano DAP at 30 DAS @ 4 ml l^{-1} of water (T_5) and significantly superior over control and rest of treatments. The lowest number of tubers plot^{-1}, weight of tubers plant^{-1} (g) and tuber yield plot^{-1} (kg) (5.70, 245.67 g and 13.50 kg) was recorded with treatment T_1 (control). There was positive effect of weight of tuber plant^{-1} with total tuber yield and biological yield which were increased due to increase in nutrient availability and high nutrient uptake due to the combination of nano urea and nano DAP. The nano fertilizers had significantly effect on crop yield. They further noted that the higher yield attributes and yield of crop were recorded with the combination of 100 % NPK along with nano-urea and nano-zinc. Similar result reported by Al-Juthery *et al.* (2018). They reported that application of Nano Super Micro Plus (NSMP) + Seaweed Ibanad Multi (SW) + Growth Regulator Hypertonic (HP) was superior in crop yield and nutrient content than other treatments.

Crop yield

Yield of tuber in potato was significantly influenced by nano fertilizers. Among the different parameters, total yield of tuber (q ha^{-1}), unmarketable yield (q ha^{-1}) and marketable yield (q ha^{-1}) (335.08 q ha^{-1}, 2.20 q ha^{-1} and 332.88 q ha^{-1}) were increased with the application of 75% RDF + foliar application of nano urea and nano DAP at 30 DAS @ 4 ml l^{-1} of water (T_6) which was at par with the application of 50% RDF + foliar application of nano urea and nano DAP at 30, 45 DAS @ 4 ml l^{-1} of water and 50% RDF + foliar application of nano DAP at 30 and 45 DAS @ 4 ml l^{-1} of water (T_8) and it was significantly superior to control and rest of treatments. Further data showed that the application of 50% RDF + foliar application of nano urea at 30, 45 DAS @ 4 ml l^{-1} of water (T_7) recorded significantly higher total yield of tuber and marketable yield over control treatments and it was at par with 75% RDF + foliar application of nano DAP at 30 DAS @ 4 ml l^{-1} of water (T_5), 75% RDF + foliar application of nano urea at 30 DAS @ 4 ml l^{-1} of water (T_4), 100% RDF and 75% RDF (T_3). Lowest total yield of tuber (q ha^{-1}) and marketable yield (q ha^{-1}) (160.71 q ha^{-1}, and 149.21 q ha^{-1}) were recorded with the application of control treatment (T_1). In comparison to control (T_1), there was 52.03 % increase in tuber yield with the application of 75% RDF + foliar application of nano urea and nano DAP at 30 DAS @ 4 ml l^{-1} of water (T_6). The lowest unmarketable yield (2.20 q ha^{-1}) was recorded with the application of 75% RDF + foliar application of nano urea and nano DAP at 30 DAS @ 4 ml l^{-1} of water (T_6) which was at par with the application of 50% RDF + foliar application of nano urea and nano DAP at 30,45 DAS @ 4 ml l^{-1} of water and 50% RDF + foliar application of nano DAP at 30 and 45 DAS @ 4 ml l^{-1} of water (T_8) and it was significantly inferior to control and rest of treatments. This might be due to the fact that nano urea and nano DAP increased average weight of individual tuber, more

Table1. Effect of nano urea and nano DAP on growth parameters of potato at different growth stages

Treatment details	Plant height (cm)			Dry weight accumulation (g plant^{-1})			Leaf area (cm^2 plant^{-1})	Leaf area index at
	30 DAS	60 DAS	harvest	30 DAS	60 DAS	harvest	at 60 DAS	60 DAS
T_1 - Control (No Spray)	24.73	40.63	48.07	4.83	7.00	13.33	1459.87	2.40
T_2 - 100% RDF	27.00	46.40	55.27	6.07	10.83	17.33	2177.17	3.63
T_3 - 75% RDF	26.37	45.47	53.97	5.67	9.73	16.00	2100.33	3.50
T_4 - 75% RDF + Foliar application of nano urea at 30 DAS @ 4 ml l^{-1} of water	26.00	46.60	55.90	4.67	11.77	17.33	2240.87	3.73
T_5 - 75% RDF + Foliar application of nano DAP at 30 DAS @ 4 ml l^{-1} of water	25.93	48.37	56.40	5.17	12.97	18.00	2322.00	3.87
T_6 - 75% RDF + Foliar application of nano urea and nano DAP at 30 DAS @ 4 ml l^{-1} of water	26.33	60.33	65.07	5.33	20.10	24.33	2895.66	4.83
T_7 - 50% RDF + Foliar application of nano urea 30, 45 DAS @ 4 ml l^{-1} of water	26.43	50.80	58.00	4.83	13.73	18.33	2401.13	4.00
T_8 - 50% RDF + Foliar application of nano DAP at 30, 45 DAS @ 4 ml l^{-1} of water	25.77	54.87	60.37	5.50	15.97	21.67	2759.66	4.60
T_9 - 50% RDF + Foliar application of nano urea and nano DAP at 30,45 DAS @ 4 ml l^{-1} of water	26.43	55.43	63.60	6.33	17.43	22.33	2822.78	4.70
SE(m)±	1.06	2.18	2.20	0.54	1.16	1.88	136.72	0.28
CD at 5%	-	6.53	6.60	-	3.48	5.64	409.90	0.84

Table 2. Effect of nano urea and nano DAP on yield parameters and yield of potato

Treatment details	No. of tuber plant^{-1}	Weight of tubers & plant^{-1} (g)	Tuber yield plot^{-1} (kg)	Total yield of tuber (q ha^{-1})	Unmarke-table yield (q ha^{-1})	Marke-table yield (q ha^{-1})	Biological yield (q ha^{-1})
T_1 - Control (No Spray)	5.70	245.67	13.50	160.71	11.50	149.21	220.67
T_2 - 100% RDF	7.27	460.00	17.03	202.67	10.00	202.67	273.34
T_3 - 75% RDF	6.67	376.67	15.20	180.28	10.50	169.78	245.68
T_4 - 75% RDF + Foliar application of nano urea at 30 DAS @ 4 ml l^{-1} of water	7.20	510.00	18.10	215.34	9.33	206.14	289.67
T_5 - 75% RDF + Foliar application of nano DAP at 30 DAS @ 4 ml l^{-1} of water	9.10	600.00	19.50	232.14	7.17	224.97	308.81
T_6 - 75% RDF + Foliar application of nano urea and nano DAP at 30 DAS @ 4 ml l^{-1} of water	15.10	750.33	28.15	335.08	2.20	332.88	416.74
T_7 - 50% RDF + Foliar application of nano urea 30,45 DAS @ 4 ml l^{-1} of water	10.00	643.33	21.05	250.55	5.43	245.12	329.67
T_8 - 50% RDF + Foliar application of nano DAP at 30, 45 DAS @ 4 ml l^{-1} of water	12.00	703.33	23.25	276.74	4.83	271.91	356.97
T_9 - 50% RDF + Foliar application of nano urea and nano DAP at 30,45 DAS @ 4 ml l^{-1} of water	13.17	730.00	25.62	305.32	3.97	300.99	387.66
SE(m) ±	1.12	20.54	2.09	24.95	0.94	24.51	24.79
CD at 5%	3.36	61.56	6.27	74.80	2.82	73.48	74.33

marketable grade tuber production thereby increased the total tuber yield. Higher weight of tuber ha^{-1} may be due to the good uptake of nutrients. Foliar application of nano urea and nano DAP led to an increased in metabolism which enhances the growth of roots which directly affect the yield of tuber. Dhawne *et al*. (2024) reported that the application of 50:50: 50 NPK kg ha^{-1} as basal + foliar application of nano urea @ 3 ml l^{-1} water at 20 DAS and 40 DAS enhanced the cell elongation, activity of merismatic cells, enzyimatic activity and also increased grain formation causing increased in length of $penical^{-1}$, total number of grains $penical^{-1}$, number of filled grains $panical^{-1}$. In case of biological yield, foliar application of nano urea and nano DAP had significant effect on biological yield (q ha^{-1}) (Table 2). The maximum biological yield (416.74 q ha^{-1}) was recorded with treatment T_6 *i.e.,* 75% RDF + foliar application of nano urea and nano DAP at 30 DAS@ 4 ml l^{-1} of water. Further data revealed that the application of 50% RDF + foliar application of nano urea 30, 45 DAS @ 4 ml l^{-1} of water (T_7) recorded significantly higher biological yield over control (220.61 q ha^{-1}) and rest of treatments and it was at par with 75% RDF + foliar application of nano DAP at 30 DAS @ 4 ml l^{-1} of water (T_5), 75% RDF + foliar application of nano urea at 30 DAS @ 4 ml l^{-1} of water (T_4) and 100% RDF (T_2). Application of RDF, nano urea and nano DAP might have enhanced metabolic activity and metabolism processes. This, in turn, increases the cell division and elongation processes and thus increases the majority of vegetative growth indicators. The presence of these elements might have also reduced stomatal resistance and increased stomatal conductivity, which provides the plant with enough carbon dioxide and water to continue photosynthesis and withdrawal of nutrients from the soil leading to an increase in yield. Al-Juthery *et al.* (2020) reported that the treatment of nano (N+B) made significant increase in the soft tuber yield on the other bilateral treatments (U+B), (U+Mo), and (Mo+B).

Based on the results obtained from presented investigation the following inference can be drawn. Application of 75% RDF + foliar application of nano urea and nano DAP at 30 DAS @ 4 ml l^{-1} of water was found to be best treatment in enhancing crop growth, yield attributes and yield of potato crop.

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